Early harvest affects sugarcane ratooning ability in Louisiana

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ABSTRACT

The number of sugarcane processors in Louisiana has decreased over time forcing growers to begin the harvest season earlier for fear of complete cane loss at the end of the harvest period due to freezing temperatures as winter sets in. Experiments were conducted during 2004-2008 in Louisiana, USA to investigate effects of early harvest on ratooning ability and to determine differential effects of early harvest among four cultivars grown locally. Plant-cane cv. LCP 85-384, Ho 95-988, HoCP 96-540, and L 97-128 were harvested on 1 October (early) and 1 December (mid-season). Averaged across all cultivars, the October harvest of plant-cane reduced sucrose yields ($p = 0.01$) of the first-ratoon (7.7 t/ha) compared to the mid-season harvest date (10.1 t/ha.). The sucrose yields for L 97-128 were 0.6, 3.0, and 3.9 t/ha greater ($p = 0.01$) than HoCP 96-540, LCP 85-384, and Ho 95-988, respectively, for the early harvest. A second experiment was initiated to determine the effects of two consecutive years of early harvest (plant-cane and first-ratoon) on yields of the second-ratoon. Averaged across all cultivars, the October harvest of both plant-cane and first-ratoon reduced sugar yields ($p = 0.01$) of the subsequent second-ratoon (5.5 t/ha) compared to the December harvest (10.0 t/ha). For the October harvest, LCP 85-384, HoCP 96-540, and L 97-128 had significantly higher sugar yields (6.1, 5.6, and 6.6 t/ha), respectively, relative to Ho 95-988 (3.6 t/ha). Both harvest dates for L 97-128 produced equivalent yields, indicating that this cultivar is best suited for early harvest. All cultivars had decreased yields with consecutive October harvests. It is currently suggested that growers should not harvest cane early in consecutive seasons because yields are reduced below the point of a positive return on input costs.

Keywords: harvesting date, non-mid-season harvest, ratooning, *Saccharum*, stress, sugarcane

Introduction

From 1964 to 2007, the number of sugarcane mills in Louisiana declined from 48 to 11. One of the consequences of these changes has been an increase in the duration of the crushing season, which has historically been from mid-October to late-December. Unlike many other sugarcane industries, Louisiana often receives freezing temperatures during the latter part of the harvest. Freeze-deteriorated sugarcane causes problems in processing which can sometimes lead to factory shut-down. Thus, the most logical way to increase the crushing season has been to start harvesting earlier (mid- to late- September). Harvesting the oldest ratoons early is not a great concern for growers since this cane will be destroyed after harvest to be replanted. In many instances, the oldest ratoons are low yielding so they are harvested within a short time period leading to an early harvest of younger ratoons within the first month of the crushing season. Plant-cane is also harvested early in some cases in low lying, heavy-textured soils where rainfall during late-winter months can make mechanical harvest difficult. In addition, farm size has increased with fields often being several kilometers apart making the transportation of tracked machinery difficult. Maintaining profitable ratoon yields under these situations is often a challenge in Louisiana.

Optimizing economic return of sugarcane often involves balancing cane biomass with sucrose concentration within the stalk. Previous research indicated that biomass of cane grown in tropical climates, such as Australia, often plateaus up to 100 days before harvest, while maximum sucrose accumulation occurs at a later crop age (Muchow *et al.*, 1998). Duration of the growing season has been shown to influence both cane biomass and sucrose concentration in South Africa (Inman-Bamber, 1994). Tropical production areas typically have a 12-18 month growing season (Lawes *et al.*, 2002), while the growing season for temperate climates such as Louisiana are often as short as 6 to 9 months (Viator et al., 2009b). Thus in Louisiana and sometimes Florida, cane is often harvested before achieving maximum sucrose accumulation to sustain early-season milling operations (Gilbert *et al.*, 2006) .

Information on the duration of the growing period on sugarcane ratooning ability is limited. Previous modeling research indicated that profits were greatly reduced when sugarcane was harvested based on geographical location because sucrose accumulation was not at a maximum for all crop classes and cultivars (Muchow *et al.*, 1998). Moreover, modeling research on harvesting based on cane maturity indicated a 23% reduction in net revenue because non-optimal harvest timing reduced the number of ratoons before replanting (Higgins *et al.*, 1998). Singh and Singh (2002) indicated genetic variation for ratooning ability of early-maturing cultivars, while Jackson *et al.* (2000) reported genetic variation for ratoon development after harvester damage in wet soil. Preliminary research in Louisiana indicated a 25% reduction in ratoon yields following an early harvest of sugarcane (Viator *et al.*, 2009a). Thus, a series of experiments were conducted by scientists at the USDA-ARS Sugarcane Research Laboratory in Houma, LA to investigate the effects of early harvest on ratooning ability and to determine potential genetic variability among common Louisiana cultivars.

Materials and Methods

Both experiments were conducted on a Commerce silt loam (fine-silty, mixed, superactive, nonacid, thermic Fluvaquentic Endoaquepts) at the USDA-ARS Sugarcane Research Laboratory's Ardyone Farm located in Schriever, LA (29:42:47 N, 90:49:48 W, 2 m) in 2004 through 2008. Climatic data are listed in Table 1. Stalks of mature seed-cane varying from 1.2 to 2.4 m in length were cut with a whole-stalk harvester, and three stalks were then placed in a planting furrow and covered with five cm of soil. Metribuzin was applied at 3.4 kg a.i./ha immediately after planting and a mixture of pendimentalin (2.2 kg a.i./ha) plus atrazine (4.5 kg a.i./ha) was applied every year in March and again in May. Nitrogen, phosphorus, and potassium were applied in mid- April at 135, 34, 68 kg/ ha as an injected band on both sides of the planted line of cane. Sugarcane borers were controlled using tebufenozide at 0.1 kg a.i./ha when infestations reach thresholds defined by Louisiana State University Extension recommendations.

For experiment one, a split plot experimental design was used, with whole plots consisting of the cultivars LCP 85-384, Ho 95-988, HoCP 96-540, and L 97-128. Split plots were harvest dates, and consisted of harvesting plant-cane on 1 October and 1 December, 2005 and 2006, which corresponds to a growth period of nine and eleven months, respectively, for the two harvest dates. Cane was harvested with a chopper harvester with the field soil being dry at the time of harvest.

Experiment two was initiated in 2004 to determine the effects of the early harvesting of both the plant-cane and first-ratoon crops on the yields of the second-ratoon crop. Whole plots consisted of the same cultivars as experiment one. Split plots consisted of harvesting the plant-cane (2005 and 2006) and first-ratoon (2006 and 2007) crops on 1 October and 1 December. The subsequent second-ratoon crops were harvested on 30 October of 2007 and 2008.

For both experiments, whole plots consisted of three 1.8-m rows 60 m in length, and split plots consisted of 30 m lengths of the three 1.8-m rows. All data was taken from the center row, and all treatments were replicated four times in a randomized complete block design. In mid-August, numbers of harvestable stalks (> 1.4 m in height) were recorded from a 2 m row-length, and stalk heights were measured from 10 randomly selected stalks. Cane yield was determined by mechanically harvesting the center row of each plot with a chopper harvester and then weighing the cane using a modified high-dump field transportation wagon equipped with electronic load cells. Theoretical recoverable sucrose (TRS) level was determined from a randomly collected sample of stalk pieces (billets) from each plot using the core press method (Johnson and Richard, 2005). All data was analyzed using SAS with PROC MIXED (SAS Institute, 2001). Differences between treatment least square means were compared using the pdiff option (Saxton, 1988) at the 0.05 probability level. There were no treatment by year interactions for either study indicating that treatments showed similar results in both years, so data were averaged across years.

Results and Discussion

Experiment 1

As shown in Table 2, when averaged across all cultivars, the October harvest of plant-cane reduced cane yields of the first-ratoon by 21.5 t/ha relative to the December harvest date, which yielded 89.7 t/ha ($p = 0.01$). TRS in the subsequent first-ratoon crop was not affected by harvest date in this study regardless of cultivar. Moreover, due to the large effects on cane yield, sucrose yields, when averaged across all cultivars, were reduced 2.4 t/ha ($p = 0.01$) with the October harvest of plant-cane relative to the December harvest date, which yielded 10.1 t/ha of sucrose.

Reduced cane yield of the first-ratoon crop with the early harvest date was associated with a lower stalk population (130000 stalks/ha) relative to the December harvest date (161000 stalks/ha) ($p = 0.05$) (Table 4). When averaged across all

Table 1. Thirty year climatic data for south central Louisiana

	Average Temperature C	Low Temperature C	High Temperature C	Average Rainfall mm
Month				
January	17.6	3.1	24.2	253
February	17.2	1.4	19.4	51
March	23.8	1.7	23.6	42
April	24.3	5.0	24.2	115
May	29.3	17.8	26.7	110
June	32.2	23.9	28.6	151
July	31.4	24.4	29.2	156
Aug	33.8	26.4	30.6	87
September	31.2	23.1	28.1	267
October	27.8	9.4	27.8	91
November	21.9	7.8	21.7	109
December	19.8	3.6	23.6	93
Average	25.8	12.3	25.6	127

Table 2. Effects of plant-cane harvest date of LCP 85-384, Ho 95-988, HoCP 96-540, and L 97-128 on first-ratoon theoretical recoverable sucrose (TRS), cane yield, and sucrose yield (means of 2006 and 2007)

	TRS		Cane yield		Sucrose yield	
	October	December	October	December	October	December
Cultivar	kg/t		t/ha		t/ha	
LCP 85-384	115Aa[a]	116Aa	57.4Bb	81.0Ba	6.6Cb	9.4Ba
Ho 95-988	112Aa	111Aa	50.9Bb	83.8Ba	5.7Cb	9.3Ba
HoCP 96-540	112Aa	112Aa	80.4Ab	106.3Aa	9.0Bb	11.9Aa
L 97-128	114Aa	113Aa	84.2Aa	87.6Ba	9.6Aa	9.9Ba
Average	**113a**	**113a**	**68.2b**	**89.7a**	**7.7b**	**10.1a**

[a] Means within a column followed by the same uppercase letter or within a row followed by the same lower case letter are not statistically different using the F probability-values and the PROC MIXED macro as described by Saxton (1998) at the 0.05 probability level.

cultivars, stalk height in the subsequent first-ratoon crop was not affected by harvest date.

When one compares the first-ratoon yields of the four cultivars when harvested early the previous year, the cane yields for L 97-128 were 3.8, 26.8, 33.3 t/ha greater than for HoCP 96-540, LCP 85-384, and Ho 95-988, respectively (p = 0.03) (Table 2). Moreover, the cane yields of HoCP 96-540 were 23.0 and 29.5 t/ha greater than the yields of LCP 85-384 and Ho 95-988 (p=0.05). There were no differences in TRS due to harvest date, but at the early harvest date sucrose yields of L 97-128 were 0.6, 3.0, and 3.9 t/ha greater than HoCP 96-540, LCP 85-384, and Ho 95-988, respectively (p = 0.03) (Table 2). For the early plant-cane harvest, subsequent first-ratoon sucrose yields of HoCP-540 were 2.4 and 3.3 t/ha greater than those of LCP 85-384 and Ho 95-988, respectively (p = 0.03). One must note that the yield rankings for both cane and sucrose of the cultivars for the December harvest date are different than those for the October harvest date.

The reduced cane yields of LCP 85-384 and Ho 95-988 when harvested early were reflected by a marked decrease in stalk population and height relative to Ho 96-540 and L 97-128 (Table 2). Relative to the averages for HoCP 96-540 and L 97-128, LCP 85-384 had reductions in stalk population and height of 11 000 stalks/ha and 29 cm, while Ho 95-988 had reductions in stalk population and height of 28 000 stalks/ha and 50 cm (p=0.04) (Table 4).

When one compares the yields of each variety with each harvest date, L 97-128 was the only variety not to have a significant reduction in sucrose yield when harvested early. Therefore, it appears that L 97-128 is the best cultivar to plant where an early harvest is required, with HoCP 96-540 showing moderate ratooning ability after an early harvest.

Sucrose partitioning to the leaf, stalk, or meristem tissues located primarily at the shoot and root apices can vary with genotype, developmental stage, and the environment in which the plant is grown (Moore, 2005). For the October harvest date investigated in this experiment, sugarcane in Louisiana is just beginning the maturation stage (unpublished maturity studies), so different tissues, to include the underground stubble buds that will produce the subsequent ratoon crop, are still actively competing for photoassimilates. Thus, one would expect different cultivars with varying levels of sucrose partitioning to the stalk and root apices to respond differently to an early harvest. L 97-128 is an early maturing variety, thus may have a greater portion of photoassimilates to partition into the roots instead of the stalk relative to the other cultivars included in this study that are later maturing.

In the tropical climate of South Africa, ratooning ability was decreased by 8 to 24% with a late harvest (Oct-Dec) relative to early harvest (June-Sept) (Lawes *et al.*, 2002). One must note that an early harvest in a tropical climate increases the growth period of the subsequent ratoon because of continuously warm temperatures adequate for cane re-growth. In sub-tropical climates, all cane regardless of age is winterkilled when ambient temperatures fall to 0 or 1°C. The crop does not reemerge in the spring until soil temperatures reach 18°C (Mongelard, 1972). Thus, an early harvest in this climate does not increase the duration of the growing season for the subsequent ratoon crop. Lawes *et al.* (2002) also indicated that harvest date did not affect sucrose concentration in the subsequent ratoon crop as is indicated in this study as well.

Experiment 2

The October harvest of both plant-cane and first-ratoon crops reduced cane yields of the subsequent second-ratoon crop (47.0 t/ha) relative to the December harvest date (86.4 t/ha) (Table 3). TRS of the second-ratoon crop was not affected by harvest date of the previous crop. On the other hand, sucrose yields were reduced by 4.5 t/ha relative to the December harvest date which yielded 10.0 t/ha. The reduction in cane yield with the consecutive early harvest dates was associated with a reduction in stalk population (106000 stalks/ha) relative to the later harvest date (165000 stalks/ha) (p=0.03) (Table 4). When averaged across all cultivars, stalk height of the second-ratoon was not affected by harvest date in the previous years.

When one compares the second-ratoon yields of the four cultivars harvested early the two previous years, the cane yields for LCP 85-384, HoCP 96-540, and L 97-128 were significantly higher (52.1, 47.4, and 57.4 t/ha) than Ho 95-988 (31.0 t/ha) (p = 0.02) (Table 3). Furthermore, the sucrose yields for LCP 85-384, HoCP 96-540, and L 97-128 were significantly higher (6.1, 5.6, and 6.6 t/ha) than Ho 95-988 (3.6 t/ha) (p = 0.02) (Table 3). The early-harvest reduction in cane yields with Ho 95-988 was not reflected in reductions in either stalk population or height relative to the other cultivars suggesting that some other yield parameter that was not measured, such as stalk density, may have been affected (Table 4).

Table 3. Effects of plant-cane and first-ratoon harvest date of LCP 85-384, Ho 95-988, HoCP 96-540, and L 97-128 on second-ratoon theoretical recoverable sugar (TRS), cane yield, and sucrose yield (means of 2007 and 2008)

	TRS		Cane yield		Sucrose yield	
	October	December	October	December	October	December
Cultivar	kg/t		t/ha		t/ha	
LCP 85-384	117Aa[a]	115Aa	52.1Ab	78.3Ba	6.1Ab	9.0Ba
Ho 95-988	116Aa	117Aa	31.0Bb	79.5Ba	3.6Bb	9.3Ba
HoCP 96-540	118Aa	118Aa	47.4Ab	100.8Aa	5.6Ab	11.9Aa
L 97-128	115Aa	114Aa	57.4Ab	86.8Ba	6.6Ab	9.9Ba
Average	**117a**	**116a**	**47.0b**	**86.4a**	**5.5b**	**10.0a**

[a] Means within a column followed by the same uppercase letter or within a row followed by the same lower case letter are not statistically different using the F probability-values and the PROC MIXED macro as described by Saxton (1998) at the 0.05 probability level.

Table 4. Effects of harvest date on first-ratoon and second-ratoon stalk population and height

	First-ratoon				Second-ratoon			
	Stalk population		Stalk height		Stalk population		Stalk height	
	October	December	October	December	October	December	October	December
Cultivar	1000 stalks/ha		cm		1000 stalks/ha		cm	
LCP 85-384	129Bb[a]	154Ba	152Bb	160Aa	126Ab	174Aa	136Ba	142Ba
Ho 95-988	112Cb	150Ba	131Cb	143Ba	108Ab	164Ba	130Ba	136Ba
HoCP 96-540	143Ab	171Aa	176Aa	174Aa	91Bb	150Ba	150Aa	150Aa
L 97-128	137Ab	167Aa	186Aa	188Aa	100Ab	170Aa	150Aa	158Aa
Average	**130b**	**161a**	**161a**	**166a**	**106b**	**165a**	**142a**	**147a**

[a] Means within a column followed by the same uppercase letter or within a row followed by the same lower case letter are not statistically different using the F probability-values and the PROC MIXED macro as described by Saxton (1998) at the 0.05 probability level.

Analyzed separately, all of the cultivars had a significant reduction in sucrose and cane yield when harvested at the October harvest for the two previous years. The reductions in sucrose yields with the early harvests for LCP 85-384, Ho 95-988, HoCP 96-540, and L 97-128 were 32, 61, 53, and 33%, respectively. Even though the percentage yield reduction for L 97-128 is the lowest, yield levels were similar for the L 97-128, LCP 85-384, and HoCP 96-540. In other words, the excellent ratooning ability of L 97-128 in experiment one was not present with the additional stress of two consecutive early harvests in experiment two.

The balance of sucrose and carbon partitioning to the stalk and sugarcane root system is very poorly understood and, consequently, the physiological trade-offs between allocation to roots and yield components is unknown (Smith *et al.*, 2005). Wood and Wood (1967) reported that the root system of the previous crop continued to sustain the crop to some extent for at least 4 months after harvest, and other research indicated that the growth of the old root system is critical to survival of the stool and growth of the ratoon crop (Glover, 1968; Ball-Coelho *et al.*, 1992). Therefore, one would expect that, if by harvesting early before the is crop is fully matured, the level of photoassimilates partitioned into the root system is invariably reduced, consequently, ratooning is adversely impacted. The current study supports this theory.

Similar to the current study, previous research indicated that the ideal harvest period for ratooning in terms of cane biomass only partially coincides with the ideal period for sucrose concentration in the previous crop (Lawes *et al.*, 2002). Thus, ratooning must be taken into account when scheduling harvest. Second-ratoon sugar yields of 5.5 t/ha (average of all cultivars when harvested early for two consecutive years) are not economically feasible in Louisiana because input costs will exceed revenue (Salassi and Deliberto, 2007). Moreover, the number of ratoons harvested before the crop is replanted affects both farm and mill profitability (Patch *et al.*, 1986). The production of only two crops from one planting is not an economically sustainable practice in Louisiana sugarcane production.

Conclusions

L 97-128 ratoons better than LCP 85-384, Ho 95-988, and HoCP 96-540 when harvested early for one year. Both harvest dates for L 97-128 had equivalent yields, so this variety is best suited for early harvest. All cultivars had decreased yields with consecutive years of early harvests. It is currently suggested that growers should not harvest cane early in consecutive seasons because yields are reduced below the point of a positive return on input costs. Ongoing studies are screening newly released cultivars for ratooning ability after early harvests. Finally, other research conducted by scientists at the USDA-ARS Sugarcane Research Laboratory in Houma, LA is focused on cold-tolerant cultivars that could extend the harvest season into late-January, therefore allowing a later start date to the harvest.

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